Water Resources

WILLOW CREEK BASIN

STORAGE SITE FEASIBILITY INVESTIGATIONS

Alberta
ENVIRONMENT

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WILLOW CREEK BASIN

STORAGE SITE FEASIBILITY INVESTIGATIONS

Alberta Environment
Water Resources Management Services
Planning Division

October, 1986

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ACKNOWLEDGEMENTS

Timely and valuable input to the study was provided by members of a Technical Committee listed in Appendix A. Their contributions are gratefully acknowledged.

The members of the volunteer Public Advisory Committee established a communication linkage between study personnel and the people of the region. The participation of this committee was very helpful and much appreciated.

The contributions of other Departments--Alberta Agriculture, Alberta Transportation and Alberta Recreation & Parks--are gratefully acknowledged.

This summary report was prepared by L.K. Szojka and J.R. Hart, Planning Division, Alberta Environment.

SUMMARY

Feasibility studies were carried out for six potential storage projects in the Willow Creek Basin:

Site 1.	Claresholm Site	- 32,000 acre-feet
Site 2.	Pine Coulee (Offstream) Site	- 41,000 acre-feet
		- 20,000 acre-feet
	Willow Creek (Onstream) Site	- 59,000 acre-feet
		- 40,000 acre-feet
Site 3.	Kuntz Creek Site	- 48,000 acre-feet.

Evaluation of the projects were based on physical, economic, environmental and social considerations. The most feasible project from all considerations is a 41,000 acre-foot offstream storage reservoir at Site 2, Pine Coulee, at a total cost of $34.0 million. This project would provide a more secure water supply for municipal needs, meet stock-watering needs along the creek and provide a source for pumping under emergency conditions, meet existing irrigation needs and provide for some expansion, and enhance fishery and recreational pursuits. The 41,000 acre-foot Pine Coulee project has considerable local support.

A smaller 20,000 acre-foot offstream project could be constructed in Pine Coulee for about $21.9 million. The smaller project would support less irrigation and, from an economic viewpoint, would be less attractive than the larger one.

Field investigations for the onstream dams at Sites 1 and 3 were not carried out because of opposition from landowners. However, on the basis of available information on these two sites and from investigations of the Willow Creek Site 2 onstream dam near Pine Coulee, there appears to be no particular advantages to the onstream sites over the Pine Coulee

offstream site. The Site 2 onstream project would cost about as much as the offstream Pine Coulee project (with comparable storage capacity) and would have greater environmental and social impacts.

Based on this investigation, it is concluded that a 41,000 acre-foot offstream storage project at the Pine Coulee site is the most feasible project for multipurpose water use in the Willow Creek Basin.

INTRODUCTION

In 1983, Alberta Environment initiated a planning program in response to local concerns related to water supply shortages and water management conflicts in the Willow Creek Basin. The program was to address immediate concerns in the short term, and to develop a water management strategy for the basin in the long term. Terms of reference for a comprehensive planning program were drafted and, by June, 1984, an inventory of potential storage sites in the basin had been completed.

With the severe drought in 1984, municipal water supply concerns became acute and it was necessary to completely shutdown all irrigators along Willow Creek. These drought-related problems prompted irrigators and representatives of the municipalities in the area to form the Willow Creek Watershed Association to make their concerns known to the provincial government, and to request immediate action to resolve water management problems in the basin.

At the direction of the Minister of Environment, the Department accelerated planning activities in the basin by focusing on three potential storage sites: Willow Creek Site 1 near Claresholm; Pine Coulee Site 2, offstream storage west of Stavely; and Willow Creek Site 3 near Kuntz Creek (Figure 1). The feasibility of storage at the three sites was investigated, considering engineering, economic, social and environmental factors. During the course of the study, the Willow Creek onstream storage site (Willow Creek Site 2), which has essentially the same reservoir area as Pine Coulee Site 2, was included in the investigations. These investigations are the subject of this report.

STUDY PROCESS

A twelve-member Public Advisory Committee was formed to assist the Department in the feasibility investigations. This committee provided a vehicle for communication among people in the region and provided information to planning staff to assure that local issues and concerns were fully understood. The volunteer committee had representation from the municipalities of Claresholm, Nanton, Stavely and Granum, the Municipal District of Willow Creek and Improvement District No. 6; the Fish and Game Association; the Historical Society; Willow Creek irrigators; and landowners from each of the potential storage areas. The committee was chaired by Mr. Duane Southgate from Nanton.

A program of engineering, economic, social and environmental studies was developed and co-ordinated by the Planning Division of Alberta Environment. The engineering component of the program, which involved surveys, drilling, designs and cost estimates, was co-ordinated by the Design and Construction Division of Alberta Environment.

A team of Alberta Environment staff members were responsible for the conduct of individual component studies. The various components and members of the team are listed in Appendix A.

During the course of the planning program, the scope of the investigations were modified to reflect local desires and sensitivities. Access to private land to carry out field investigations at Sites 1 and 3 was refused. The designs and cost estimates for these two sites are therefore based on limited information and are not at the same level of confidence as those for Site 2 on Pine Coulee. At the request of the Public Advisory Committee, a site on Willow Creek just downstream from the confluence with Pine Coulee was investigated. Most of the reservoir area at this site would be along Pine Coulee; however, it would have a greater storage potential than the offstream site and would not require diversion

works from Willow Creek. Field investigations were carried out at this onstream site and cost estimates were prepared at the same level of confidence as for the Pine Coulee site.

Reports prepared on various components of this study are listed in Appendix B.

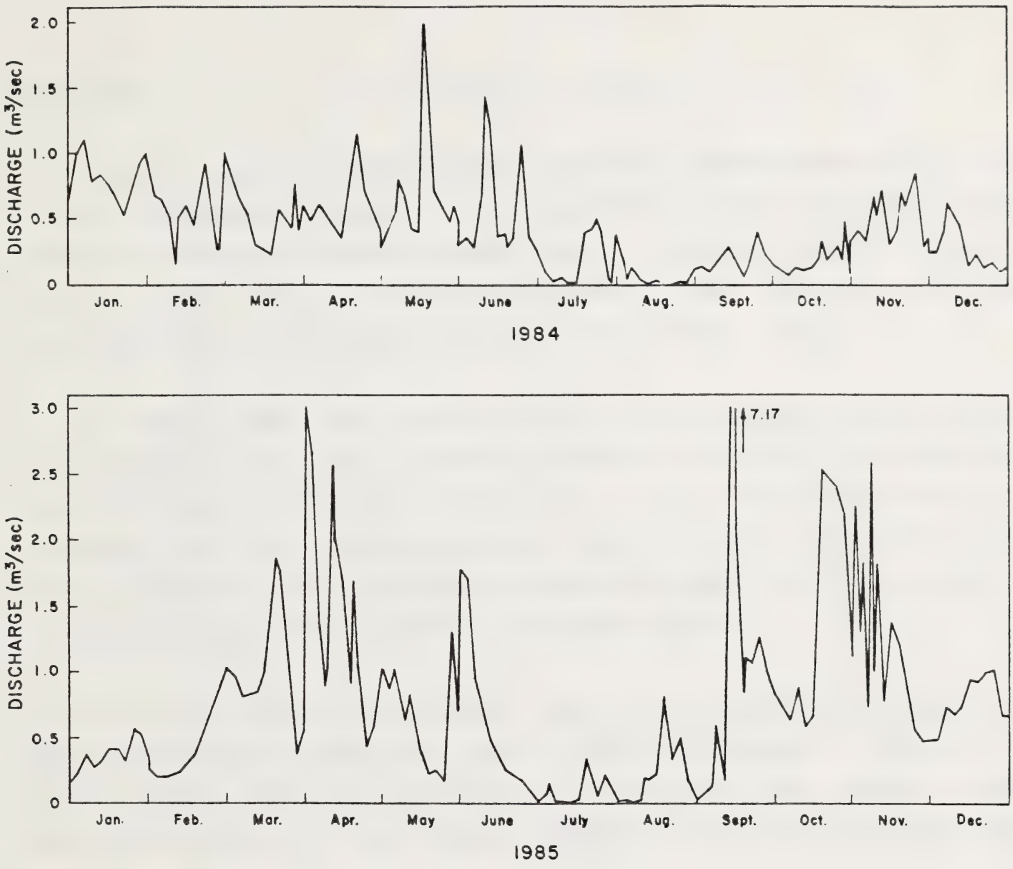
WATER SUPPLY

Hydrological studies conducted by Technical Services Division, Alberta Environment and by Klohn Leonoff Consultants established the natural flows for Willow Creek Basin that were the basis for assessing the yield potential of each storage site considered. The mean annual natural flows at various locations in the basin have been estimated as follows:

1.	Willow Creek above Chain Lakes	- 28,300 acre-feet.
2.	Willow Creek below Lane Creek	- 68,600 acre-feet.
3.	Willow Creek near Claresholm	- 85,800 acre-feet.
4.	Willow Creek near Granum	- 110,300 acre-feet.
5.	Willow Creek near Nolan	- 118,100 acre-feet.

Within the drainage basin the only storage reservoir that provides some flow regulation is the 14,000 acre-foot Chain Lakes Reservoir. Because of its limited storage and its location in the headwaters of the basin, the reservoir does not control sufficient amounts of runoff to be of major benefit to irrigators and its usefulness in supplying municipal water needs is limited. Chain Lakes Reservoir has been operated chiefly to meet municipal, recreation and livestock water use requirements. Storage investigations, therefore, were centered on sites near Claresholm, centrally located in the basin and upstream from the reach where irrigation is prevalent.

The plight of the municipalities and irrigators in the basin can be best demonstrated by reviewing the 1984 and 1985 runoff records at Claresholm illustrated below.



HYDROGRAPH OF WILLOW CREEK NEAR CLARESHOLM - 1984 AND 1985 (STA. 05AB021)

From these hydrographs, it can be seen that water supply was very limited downstream of Claresholm by early July in both 1984 and 1985. in these two years, as well as in other years, greater supply of water is available in spring and early summer. To increase the available supply after the high runoff period, storage is necessary to entrap early runoff and provide the means for carryover later in the season. Annual carry-over is also required so that water stored in high runoff years can be used in subsequent lower runoff years.

WATER USE

Lack of secure long-term water supply in the Willow Creek Basin has raised considerable concern in the population centres of Granum, Claresholm and Stavely in recent drought years. Livestock watering is also a concern in the area. Surveys carried out in 1982 identified 615 livestock operations in the Municipal District of Willow Creek.

In April, 1984 there were a total of 39 irrigation license holders along Willow Creek with a water allocation totalling 7,700 acre-feet. From field observations carried out in 1983 in the Willow Creek Basin, an estimated total of 8,049 acres were being irrigated from Willow Creek with a capability for a maximum withdrawal of about 130 cfs (assuming all irrigators are withdrawing water at the same time).

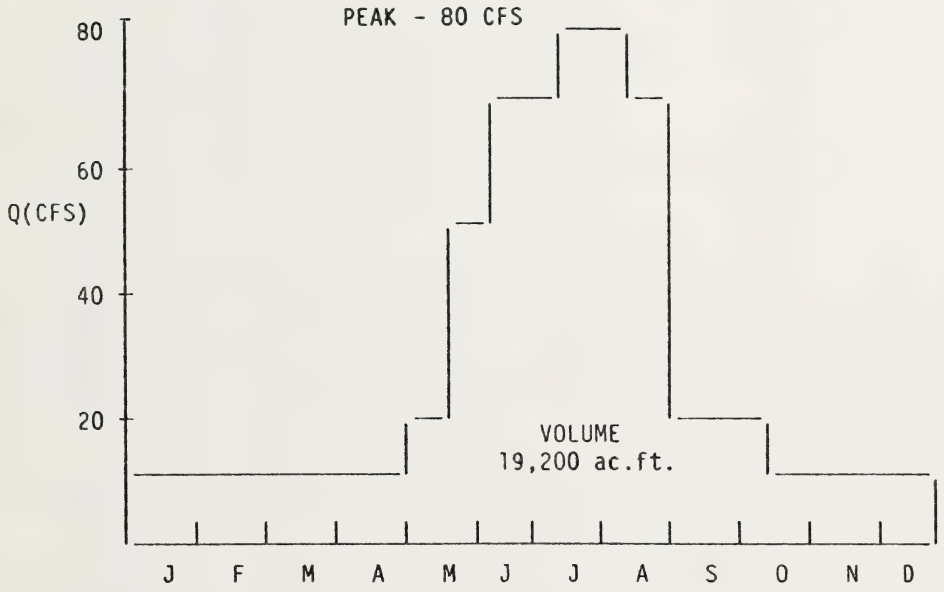
For this study, the present level of irrigation development was considered to be 8,000 acres, with a peak requirement of 80 cfs. The demand pattern shown in the following sketch was based largely on more detailed studies of irrigation water demand in the Little Bow River Basin.

For planning purposes, it was assumed that a winter flow of 10 cfs would meet the needs of livestock watering and municipal use. A more detailed study of instream flow needs is necessary to establish flow requirements to serve various existing and potential uses.

Storage-draft curves were developed for the reservoirs investigated, indicating flows available for additional consumptive use in a demand pattern suitable for supplying irrigation needs. The level of irrigation expansion that could be supported by various storage options was based upon an annual irrigation withdrawal of 1.5 feet (including losses). This irrigation requirement was estimated based on studies in the Little Bow River Basin and experience in other areas.

WILLOW CREEK WATER USE

Irrigation Demand Based on 8,000 Acres



Alberta Agriculture (August, 1985) estimated that there are 26,000 acres of land irrigable through direct pumping from the Willow Creek. Development beyond 26,000 acres would require a canal distribution system which would have substantial costs. There are in the order of 60,000 acres of land that could be irrigated in the basin provided water was available, and provided economics would justify expansion beyond the 26,000 acre level by construction of a distribution system.

From information received from the Public Advisory Committee, it is evident that security of water supply is a main concern to the municipalities, ranchers and feedlot operators and irrigators in the region. The development of storage will help to achieve a secure water supply. The sites investigated could provide a secure supply for existing irrigators

and permit a substantial expansion in irrigated acreage. There is sufficient landowner interest and potential in the Willow Creek Basin for irrigation expansion to occur. Ultimately, the available water supply will remain a limiting factor to full development of the irrigable land in this basin.

SITE EVALUATIONS

The planning program initially focussed on two storage sites on Willow Creek (Sites 1 and 3) and an offstream storage site on Pine Coulee (Site 2). The Public Advisory Committee endorsed the Pine Coulee Site 2 as having the first priority from their perspective. To provide a comparison of onstream and offstream sites at Pine Coulee, a 40,000 acre-foot onstream site (Willow Creek Site 2) was included in the investigations. Since the onstream site has potential for a higher storage capacity, a 59,000 acre-foot reservoir was also investigated.

Information on all sites investigated and evaluated is given in Table 1. The physical characteristics and economic, social and environmental impacts given in the table derive from component studies. Supporting documents are listed in Appendix B.

Onstream Sites 1 and 3 did not receive local support. Access for field investigations was denied by landowners. Based upon available information, Site 1 (Figure 2) would have a storage capacity of about 32,000 acre-feet and would cost in the order of $27.6 million. It would provide a water supply sufficient to expand irrigation by up to 18,700 acres. Site 3 (Figure 5) would have a storage capacity of about 48,000 acre-feet at a cost in the order of $28.7 million. It would support up to 20,000 acres of new irrigation development. Both sites would have negative social and environmental impacts.

Two reservoir sizes were investigated at the Pine Coulee offstream storage site (Figure 3). The high dam would permit storage of about 41,000 acre-feet at an estimated cost of $34.0 million. The reservoir would permit up to 21,000 acres of irrigation expansion. The lower dam would store about 20,000 acre-feet at a cost of about $21.9 million. This lower reservoir would provide sufficient water for about 11,000 acres of irrigation expansion.

TABLE 1

COMPARISON AND EVALUATION OF SITES

	WILLOW CREEK SITE 1	PINE COULEE SITE 2 HIGH	PINE COULEE SITE 2 LOW	WILLOW CREEK SITE 2 HIGH	WILLOW CREEK SITE 2 LOW	WILLOW CREEK SITE 3
PHYSICAL FEATURES						
LOCATION	Sec 12-13-28W4	Sec 34-13-28W4		Sec 28-13-28W4		Sec 2-13-30W4
MAXIMUM HEIGHT	74 feet	71 feet	54 feet	80 feet	64 feet	151 feet
FULL SUPPLY LEVEL (FSL)	3,379 feet	3,454 feet	3,437 feet	3,454 feet	3,444 feet	3,940 feet
RESERVOIR AREA AT FSL	1,027 acres	1,480 acres	940 acres	2,100 acres	1,600 acres	729 acres
STORAGE CAPACITY	32,400 ac/ft	41,000 ac/ft	19,700 ac/ft	59,200 ac/ft	40,000 ac/ft	47,300 ac/ft
IRRIGATION EXPANSION POTENTIAL	18,700 acres	21,300 acres	11,000 acres	25,000 acres	18,600 acres	20,000 acres
LANDS AFFECTED AT FSL						
FOREST RECREATIONAL	236 acres	30 acres	20 acres	126 acres	60 acres	168 acres
GRAZING	616 acres	1,390 acres	880 acres	1,848 acres	1,456 acres	430 acres
CROP	NIL	30 acres	20 acres	63 acres	48 acres	102 acres
OTHER	175 acres	30 acres	20 acres	63 acres	36 acres	29 acres
RESERVOIR COSTS						
LAND	N/A	$2.7M	N/A	$0.6M	N/A	N/A
BRIDGES AND CAUSEWAYS	N/A	$5.2M	N/A	$6.2M	N/A	N/A
ROAD RELOCATION	$0.2M	$0.7M	N/A	$0.7M	N/A	$0.2M
TOTAL COST						
CONCEPTUAL COST ESTIMATE-1985 *	$27.6M	$31.6M	$21.9M	$48.3M	$40.0M	$28.7M
FEASIBILITY LEVEL COST ESTIMATE	N/A	$34.0M	$21.9M	$40.0M	$34.5M	N/A
UNIT COST / ACRE-FOOT OF STORAGE	$851	$829	$1112	$676	$862	$600
UNIT COST / ACRE IRRIGATED	$1476	$1596	$1991	$1600	$1855	$1435
SOCIO-ECONOMIC BENEFIT-COST RATIO	1.00	1.08	0.69	1.03	0.86	0.99
ECONOMIC BENEFIT-COST RATIO	0.54	0.58	0.37	0.55	0.46	0.53
ENVIRONMENTAL IMPACT **						
GROUNDWATER	Not studied, seepage could be substantial.	Seepage acceptable, impact on wells is minimal. Require monitoring and mitigating measures to control seepage.		Not studied, seepage could be substantial.		Not studied, seepage could be substantial.
WATER QUALITY	NO CONCERN (1)	MODERATE IMPACT (2)		MODERATE IMPACT (2)		NO CONCERN (1)
FISH	LOCALLY DETRIMENTAL (3)	IMPROVEMENT (1)		MODERATE IMPACT (2)		LOCALLY DETRIMENTAL (3)
WILDLIFE	MODERATE IMPACT (2)	ENHANCES HABITAT (1)		MODERATE IMPACT (2)		NEGATIVE IMPACT (3)
PARKS AND LANDS	MODERATE IMPACT (2)	ENHANCES EXISTING PARK (1)		NEGATIVE IMPACT ON PARK AREA (3)		IMPACT ON VALLEY (3)
HISTORIC SITES	NEGATIVE IMPACT (3)	LOW IMPACT (1)		MODERATE IMPACT (2)		NEGATIVE IMPACT (3)
OVERALL ENVIRONMENTAL RATING	11	6	6	11	11	13
SOCIOLOGICAL IMPACT						
NUMBER OF PEOPLE SERIOUSLY AFFECTED	20	13	13	8	8	N/A
NUMBER OF RESIDENCES LOST	5	3	3	2	2	2
NUMBER OF BUILDINGS LOST	16	14	14	10	10	N/A
NUMBER OF IMPROVEMENTS LOST	35	61	59	60	58	N/A
NUMBER OF LAND OWNERS OPPOSED	7	1	1	4	4	8
OVERALL RANKING						
ECONOMIC	2	1	3	2	3	2
ENVIRONMENTAL	2	1	1	2	2	3
SOCIOLOGICAL	2	1	2	3	3	3
PUBLIC ACCEPTABILITY	NEGATIVE (3)	FAVORABLE (1)	LIMITED SUPPORT (2)	LIMITED SUPPORT (2)	NO SUPPORT (3)	STRONGLY NEGATIVE (4)
ASSESSMENT	DELETE	RETAIN	RETAIN	DELETE	DELETE	DELETE
REASONS	ENVIRONMENTAL AND SOCIAL CONCERNS.	FAVORED BY PUBLIC. PROVIDES BENEFITS WITH LEAST NEGATIVE IMPACT AT COMPARABLE COST.		ENVIRONMENTAL AND SOCIAL CONCERNS. ALSO DIRECT IMPACT ON EXISTING PARK.		ENVIRONMENTAL AND SOCIAL CONCERNS.

* CONCEPTUAL COSTS DO NOT REFLECT GEOTECHNICAL INVESTIGATIONS

** NUMERICAL RANKING IN BRACKETS

A Pine Coulee offstream reservoir would receive water from Willow Creek through a diversion weir, canal and drop structure. Design capacity of the diversion canal was set at 600 cfs. With further analysis, it may be possible to reduce this capacity to 300 cfs since canal capacities beyond 300 cfs are not frequently required. Passing flows at the weir would be regulated by gates such that the downstream flow requirements, which would include instream flow, irrigation and municipal needs would be met according to an operational guideline, while the excess flow would be directed into the Pine Coulee reservoir. The weir would be designed to pass winter flows in the order of 10 to 20 cfs coming from Chain Lakes Reservoir. Winter flows may on occasion be supplemented out of storage in the Pine Coulee reservoir. An operational plan for the Pine Coulee reservoir would be developed considering the needs of all users of the reservoir and Willow Creek, as well as instream flow needs and water quality requirements.

Groundwater studies indicate that the impact of a Pine Coulee reservoir on adjacent wells would be minimal. A monitoring program would be required to detect changes in groundwater levels so that mitigative measures could be taken if necessary. From a preliminary assessment, seepage losses from the reservoir would not present any problems. Additional investigations during the final design stage would be necessary to confirm this. The Pine Coulee offstream reservoir could complement the existing Willow Creek Provincial Park by providing opportunities for boating and reservoir fishing. Effects on transportation in the area could be satisfactorily mitigated. A mitigation plan would be developed in consultation with local authorities and Alberta Transportation.

A dam on Willow Creek downstream of Pine Coulee (Willow Creek Site 2) would create up to 59,000 acre-feet of storage, primarily in Pine Coulee (Figure 4) without the need for diversion works required for offstream storage. Two sizes of onstream dams were investigated - an eighty-foot high dam creating 59,000 acre-feet of storage at a cost of

$40.0 million, and a sixty-foot high dam creating 40,000 acre-feet of storage at a cost of $34.5 million. The high dam would provide sufficient water for up to 25,000 acres of irrigation expansion; the low dam would have a potential for up to 19,000 expansion acres.

Either size of onstream dam would inundate the Willow Creek Provincial Park. Relocation of the park would add up to $3.0 million to the cost. A streamside provincial park is unique in this region of the province and it is well attended. Expansion and improvements to the park are being planned. It would take a number of years to establish a replacement park, during which time other provincial and regional parks in the area would be congested. There is limited public support for Willow Creek Site 2, primarily due to the impact on the existing park.

From an economic perspective, there is little difference in the four sites considered. Considering agricultural benefits alone, all sites yielded direct benefit-cost ratios between 0.5 and 0.6. When indirect benefits or spinoffs are considered in a socio-economic analysis, the benefit-cost ratios become close to unity. No attempt has been made to quantify non-agricultural benefits.

A comparison of the various options reveals that there are no particular advantages to an onstream site over the Pine Coulee offstream site. The offstream site appears to have fewer negative social and environmental impacts than the onstream sites. General consensus of the Public Advisory Committee favours the 41,000 acre-foot Pine Coulee offstream storage site. This site could complement the Willow Creek Provincial Park by providing fishing and boating opportunities, provide a more secure water supply for the municipalities of Stavely, Claresholm and Granum, provide a water supply for livestock operations along Willow Creek downstream of the Coulee, provide a source for emergency pumping to stockwater dugouts and reservoirs within a 15-mile radius, and provide sufficient water to expand irrigation development by up to 21,000 acres along Willow Creek.

A lower dam at Pine Coulee would provide benefits similar to those of the high dam, but with a reduced investment and reduced potential for irrigation expansion. The benefit-cost ratio for the lower dam is significantly less than that of the high dam.

CONCLUSIONS

1. In years of low flow and high water demands, there are serious water supply problems in Willow Creek Basin. In both 1984 and 1985, problems were experienced in meeting the municipal and stockwatering needs and it became necessary to curtail irrigation water use. At present there are about 8000 acres of irrigation along Willow Creek.

2. There is substantial interest in expanding irrigation development along Willow Creek. About 26,000 acres of irrigable land has been identified within economical pumping distance of the Creek, and there are additional acres that could be supplied with a distribution system. Ultimately, water supply will be a constraint on irrigation expansion in the basin, even with storage development.

3. Storage could be provided at several locations in the Willow Creek Basin. Offstream storage on Pine Coulee is the most favorable site considering physical, social, environmental and economic factors.

4. A 41,000 acre-foot Pine Coulee offstream storage reservoir at a cost of $34.0 million would provide recreation benefits, provide a more secure water supply for stockwatering and municipal needs and permit expansion of irrigation development by up to 21,000 acres. There is extensive local support for this size and location for storage development.

5. A smaller reservoir on Pine Coulee, with a storage capacity of about 20,000 acre-feet and at a cost of $21.9 million, would have similar benefits to the larger reservoir except that irrigation expansion would be limited to less than about 11,000 acres. While the capital investment for the smaller reservoir is substantially less than for the larger reservoir, the benefit-cost ratio for the smaller reservoir is much less attractive.

5. This report and the reference documents on which it is based (Appendix B) provide sufficient information for a decision in principle with regard to storage development in the Willow Creek Basin. If a decision is made to proceed with storage development, in addition to final design and land assembly, follow-up activities should include:

   (a) Development of a transportation plan for the area in consultation with Alberta Transportation and local authorities.

   (b) Development of operation procedures for the storage reservoir considering recreation and instream flow needs as well as consumptive use needs.

   (c) Development of a water well monitoring program to provide timely identification of any changes in water quality and quantity in adjacent wells following implementation of the project.

   (d) A review of recreational opportunities and development of a recreation plan so that recreational pursuits on the reservoir can be realized in a manner which would complement the existing provincial park, and negative impacts are mitigated.

   (e) Development of a land use plan for lands adjacent to the reservoir.

   (f) A drilling program in the reservoir area to firm up the findings of preliminary investigations that concluded reservoir seepage would not be a significant problem.

6. The Public Advisory Committee played an important and effective role in the conduct of this study. The committee would be a useful vehicle for local input and liaison for follow-up activities if implementation of the project proceeds.

Appendix A

Members of the Planning Team

Alberta Environment Staff

- Program Co-ordinator	L. K. Szojka Planning Division
- Engineering Component Co-ordinator	J. Campbell Design and Construction Division
- Access for Field Activities	K. Nelson Design and Construction Division
- Design	N. Chuyen Design and Construction Division
- Geotechnical	N. Weimer Design and Construction Division
- Surveys and Mapping	J. Simanovski Technical Services Division
- Hydrology	S. Figliuzzi Technical Services Division
- Groundwater	D. Prosser Earth Sciences Division
- Economics	D. Younie Planning Division
- Social and Environmental	R. Middleton Planning Division
- Public Participation	J. Carlson Planning Division

The following staff of other departments were consulted with regard to matters under their jurisdiction:

- Agriculture	W. Wankel Resources Planning Division
- Transportation	D. Szarko Systems Planning Branch
- Recreation and Parks	P. Skydt Design and Implementation Division

Appendix B

LIST OF SUPPORTING DOCUMENTS

1. Alberta Agriculture, Project Planning Branch; Irrigation Feasibility; August 1985.

2. Alberta Environment, Design and Construction Division; Willow Creek - Pine Coulee Geotechnical Design; N. Weimer; October 1985.

3. Alberta Environment, Design and Construction Division; Willow Creek - Pine Coulee Reservoir Conceptual Report; N. Chuyen; August 1985.

4. Alberta Environment, Technical Services Division; Natural Flow Computations; S. Figliuzzi; June 1985.

5. Alberta Environment, Technical Services Division; Willow Creek Basin - Hydrologic Assessment of Reservoir Alternatives; P.G. Stevens; November 1985.

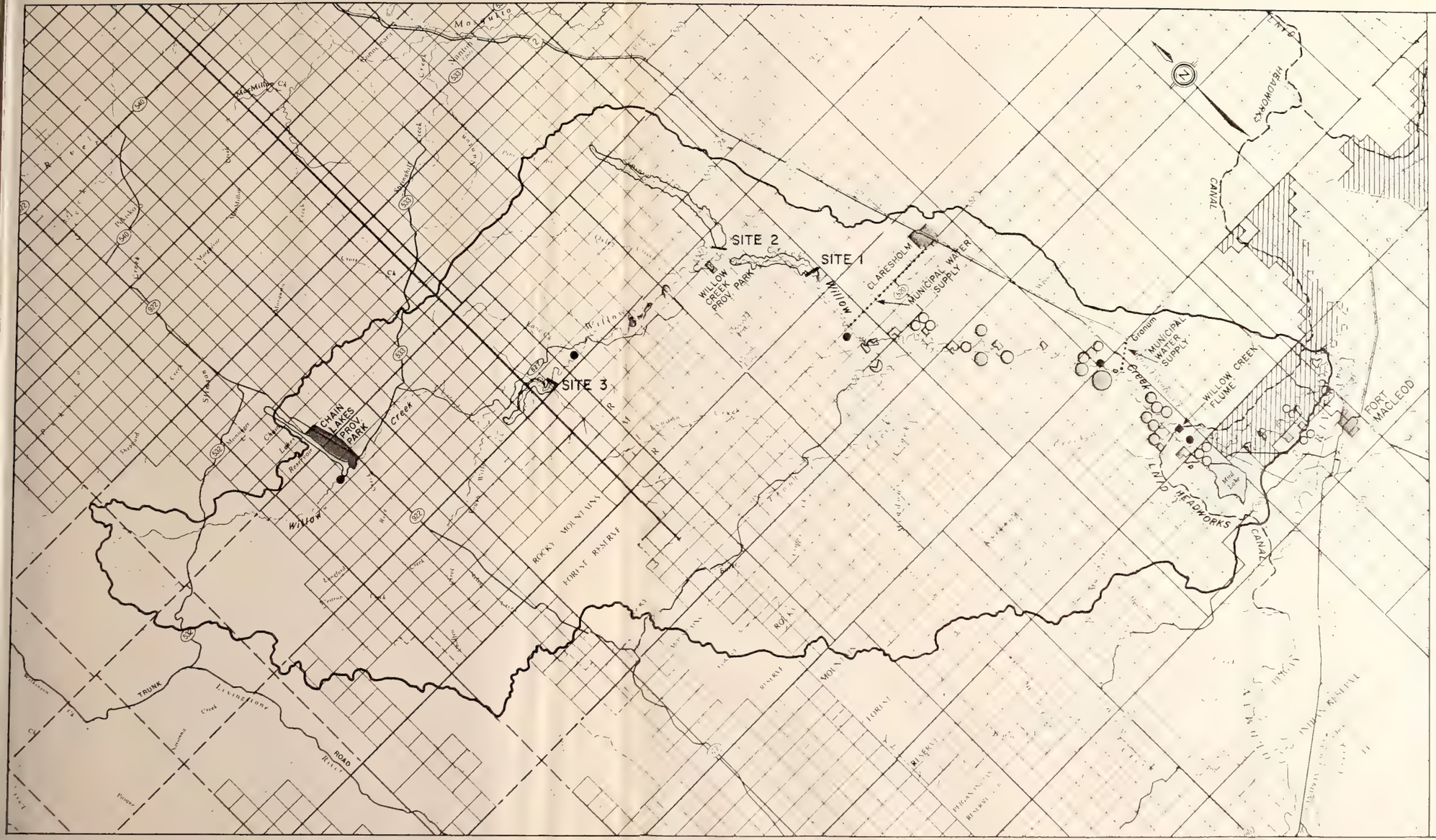
6. Alberta environment, Technical Services Division; Willow Creek Preliminary Hydrological Assessment; G. Steed; April 1984.

7. Klohn Leonoff Consultants Ltd; Preliminary Planning Study; June 1984.

8. L.G.L. Environmental Consultants; Overview Environmental Assessment; November 1985.

9. Marv Anderson & Associates Ltd; Willow Creek Basin: Economic and Financial Analysis of Irrigation Development; November 1985.

10. Piteau Engineering Ltd; Hydrogeological Assessment of Pine Coulee Reservoir; October 1985.



KEY MAP

LEGEND

- Water Survey of Canada Gauging Station (WSC)
- Irrigated Area
- Lethbridge Northern Irrigation District
- Population Centres
- Parks

SITE INFORMATION

SITE NUMBER	LOCATION	RESERVOIR							ON STREAM STORAGE
		AREA	STORAGE			MAXIMUM			
			ACRE FEET	DEPTH FEET	AREA ACRES	STORAGE ACRE FEET	DEPTH FEET	OUTFLOW CFS	ACRE FEET
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	WILLOW	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

NOTE VARIATIONS IN SIZES OF RESERVOIRS AND SITE 2 ON STREAM STORAGE NOT INCLUDED IN TABLE OR SHOWN ON PLAN

Alberta
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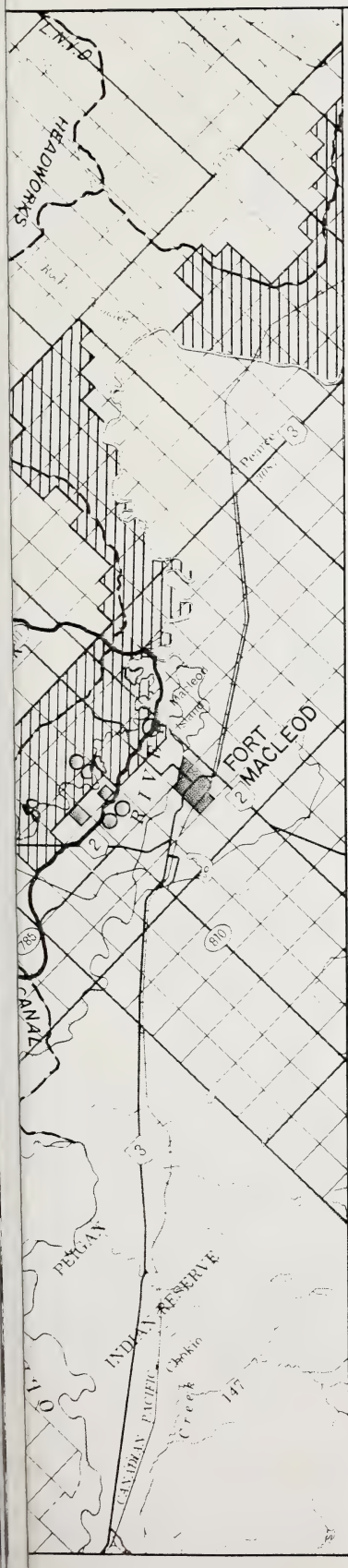
WILLOW CREEK STORAGE FEASIBILITY STUDY

LOCATION OF STORAGE SITES

SCALE 1:250 000



KEY MAP

LEGEND

- Water Survey of Canada Gauging Station (WSC)
- Irrigated Area
- Lethbridge Northern Irrigation District
- Population Centres
- Parks

SITE INFORMATION

SITE NUMBER	LOCATION CREEK	RESERVOIR AREA HA	RESERVOIR AREA ACRES	RESERVOIR STORAGE DAM³	RESERVOIR STORAGE ACRE-FEET	DAM HEIGHT METRE	DAM HEIGHT FEET	DAM LENGTH METRE	DAM LENGTH FEET
1	WILLOW	416	1027	40000	32400	22.5	74	470	1540
2	OFF STREAM	600	1482	50300	40745	21	69	450	1476
3	WILLOW	295	729	59000	47790	46	151	220	720

NOTE: VARIATIONS IN SIZES OF RESERVOIRS AND SITE 2 ON STREAM STORAGE NOT INCLUDED IN TABLE OR SHOWN ON PLAN.

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WILLOW CREEK STORAGE FEASIBILITY STUDY

LOCATION OF STORAGE SITES

SCALE 1:250 000

FIGURE 1

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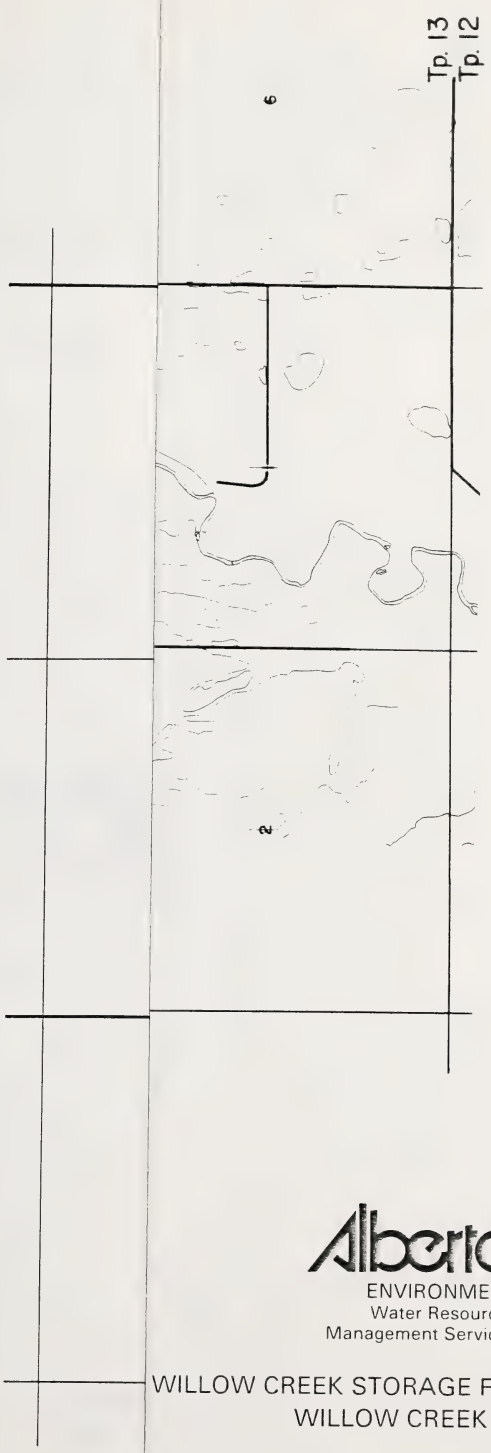
WILLOW CREEK STORAGE FEASIBILITY STUDY
WILLOW CREEK SITE 1

LOCATION PLAN

SCALE 1:30 000



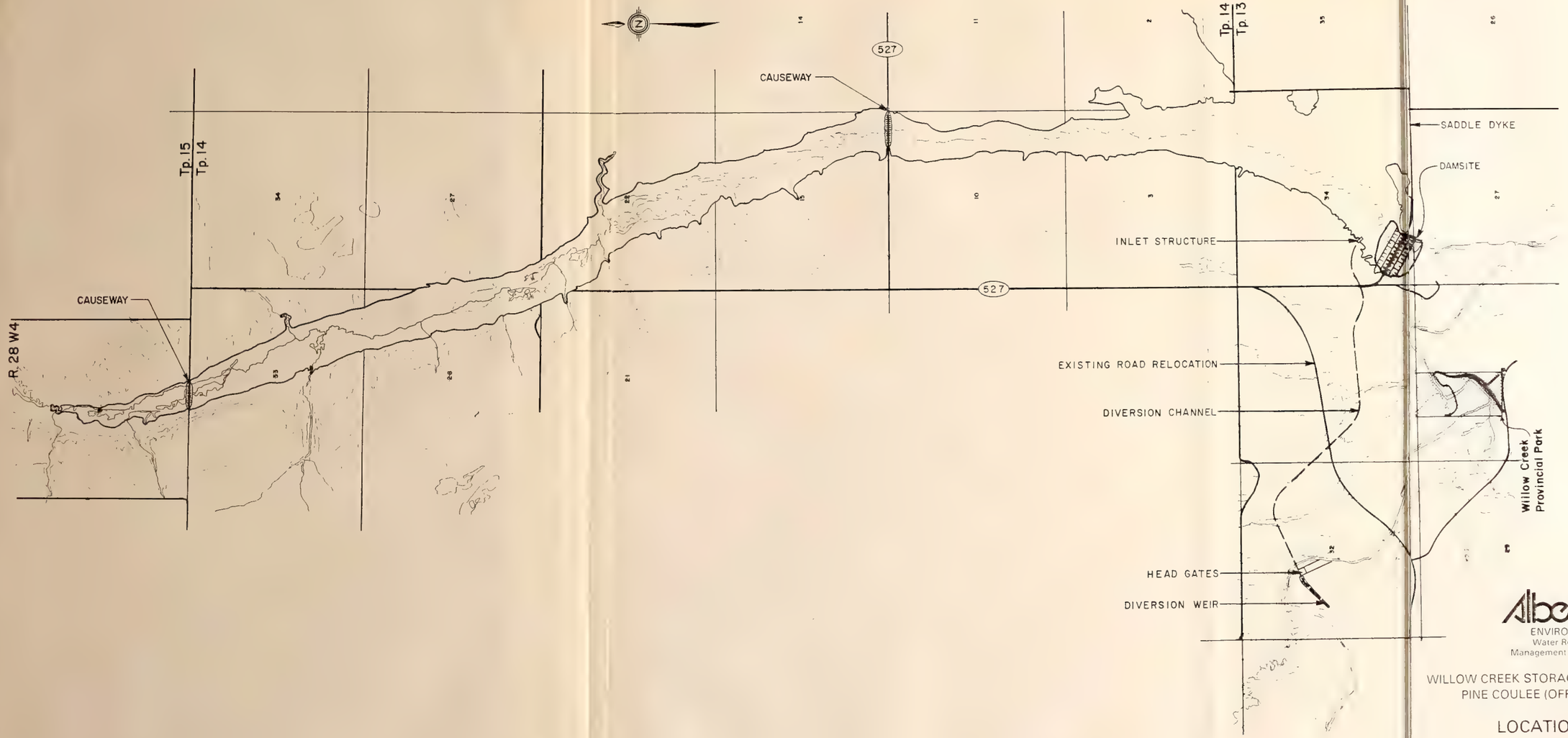
Alberta
ENVIRONMENT
Water Resources
Management Services

WILLOW CREEK STORAGE FEASIBILITY STUDY
WILLOW CREEK SITE 1

LOCATION PLAN

SCALE 1:30 000

FIGURE 2



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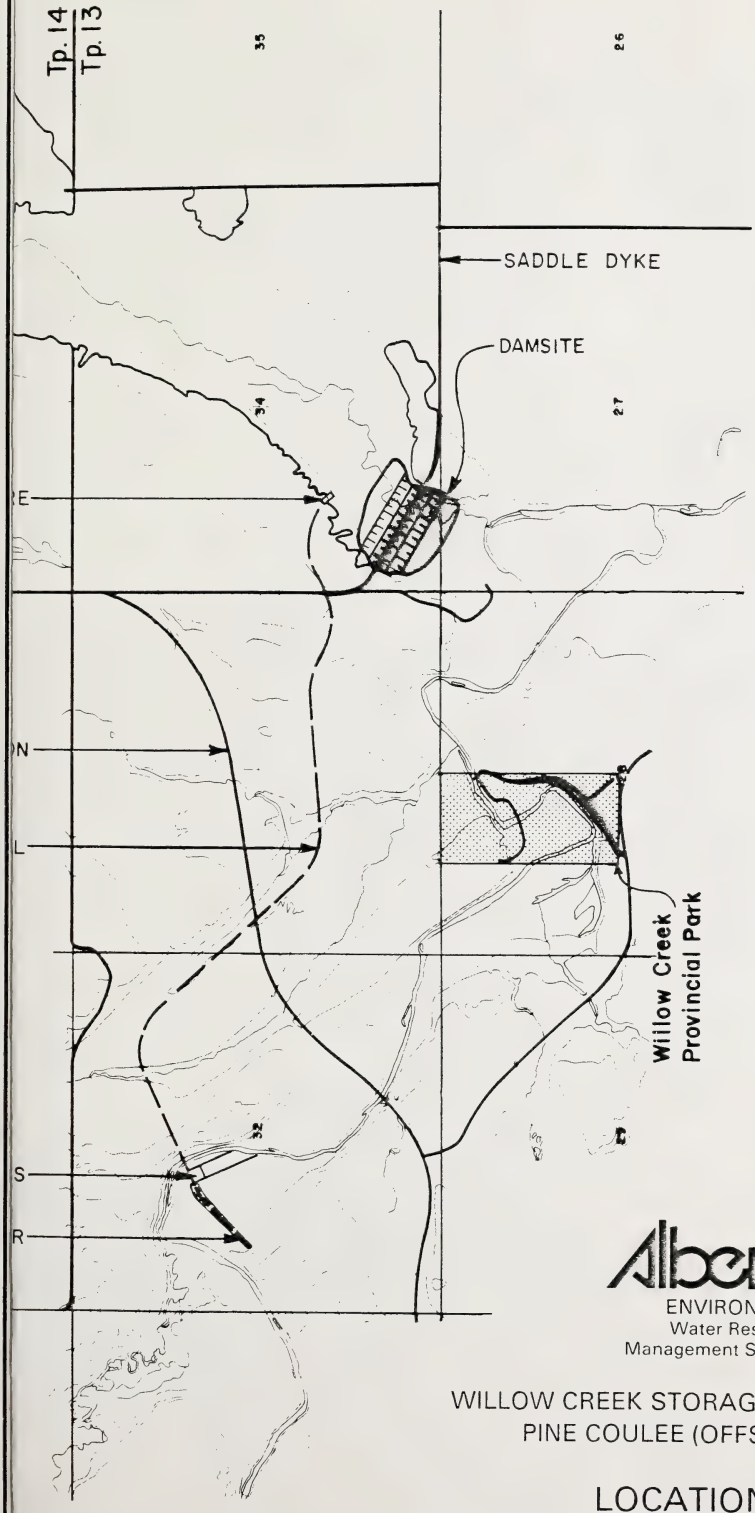
Water Resources
Management Services

WILLOW CREEK STORAGE FEASIBILITY STUDY
PINE COULEE (OFFSTREAM) SITE 2

LOCATION PLAN

SCALE 1 30 000

FIGURE 3



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ENVIRONMENT
Water Resources
Management Services

WILLOW CREEK STORAGE FEASIBILITY STUDY
PINE COULEE (OFFSTREAM) SITE 2

LOCATION PLAN

SCALE 1:30 000

FIGURE 3

Alberta
ENVIRONMENT
Water Resources
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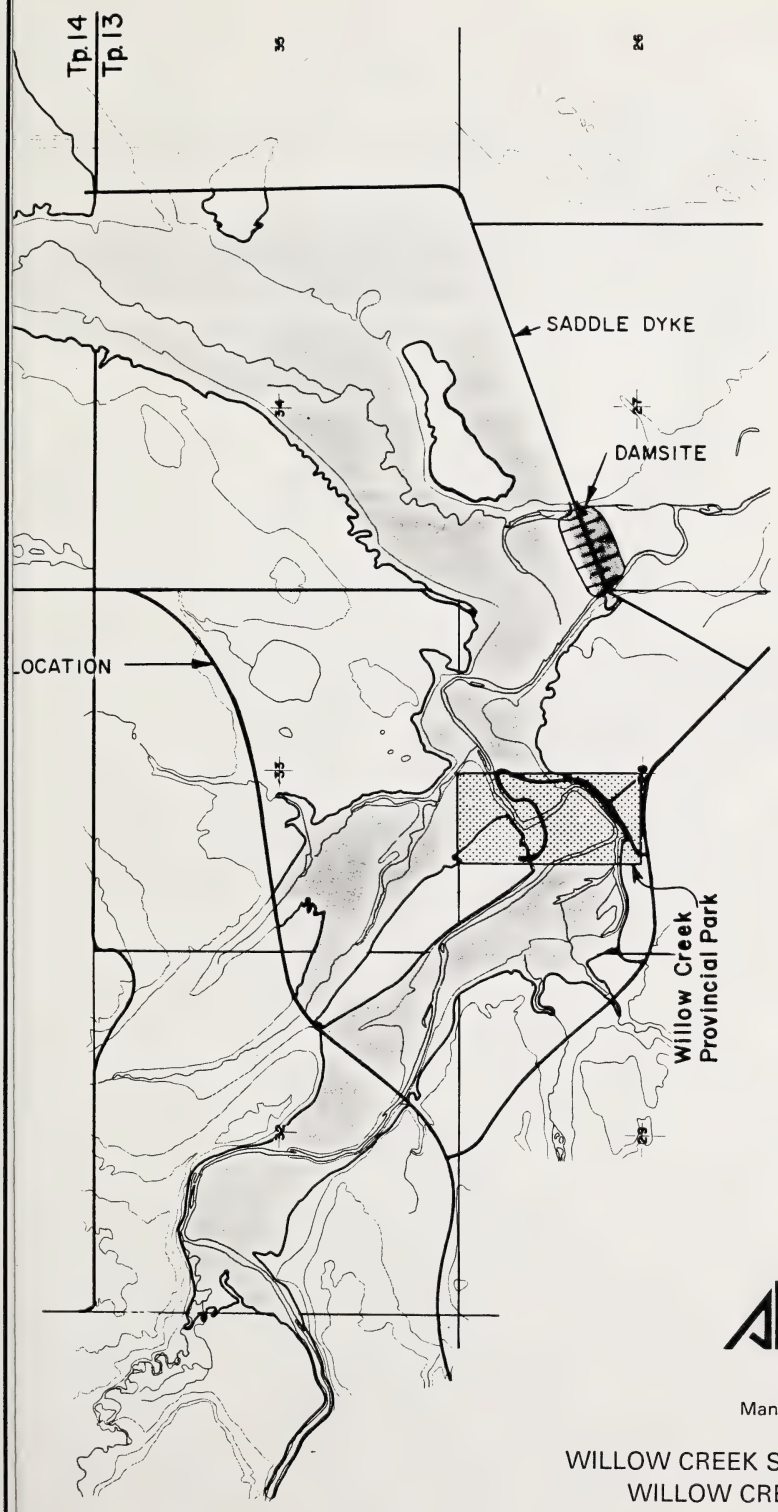
WILLOW CREEK STORAGE FEASIBILITY STUDY
WILLOW CREEK (ONSTREAM) SITE 2

LOCATION PLAN

SCALE 1:30 000



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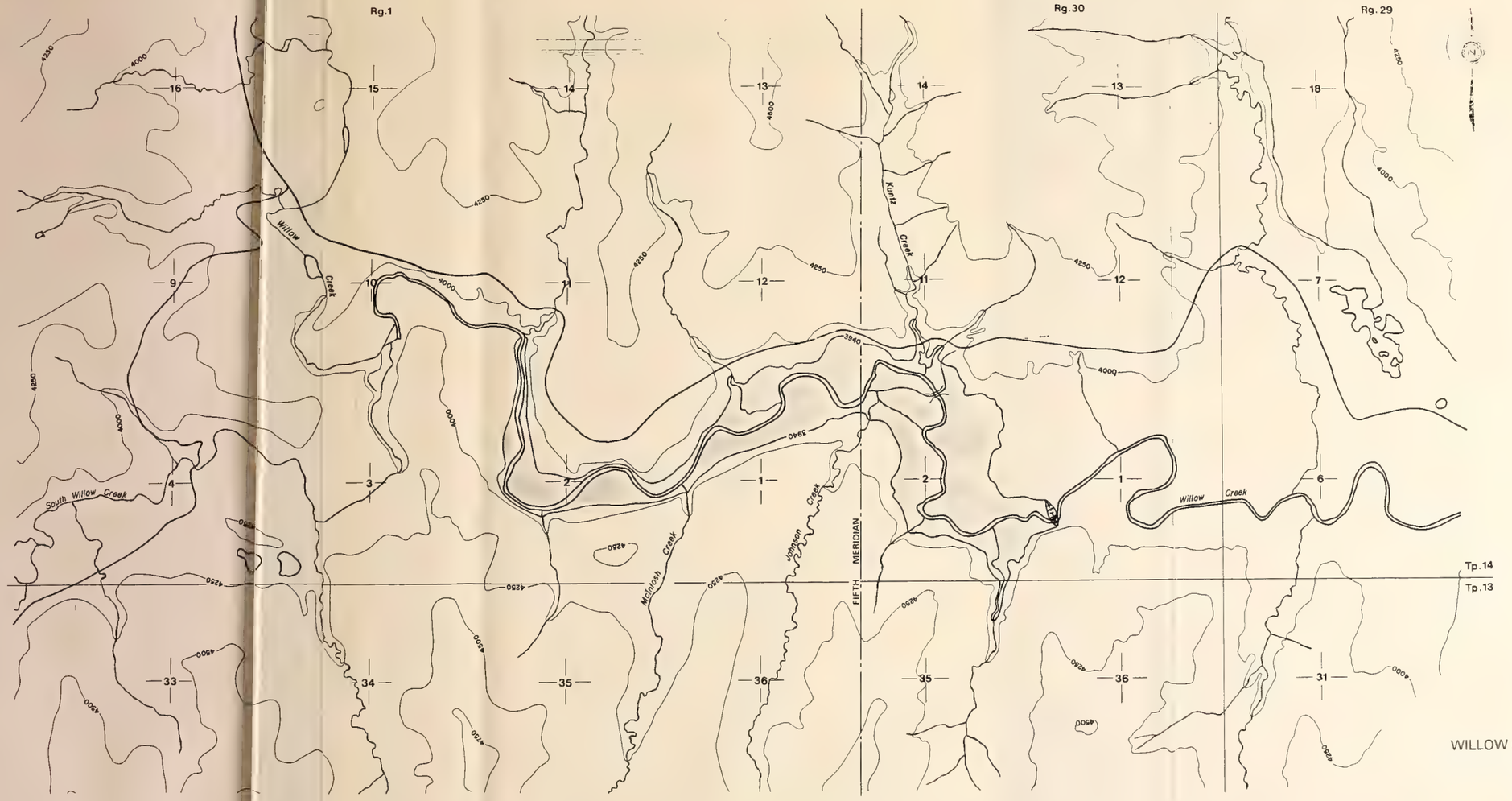
ENVIRONMENT
Water Resources
Management Services

WILLOW CREEK STORAGE FEASIBILITY STUDY
WILLOW CREEK (ONSTREAM) SITE 2

LOCATION PLAN

SCALE 1:30 000

FIGURE 4



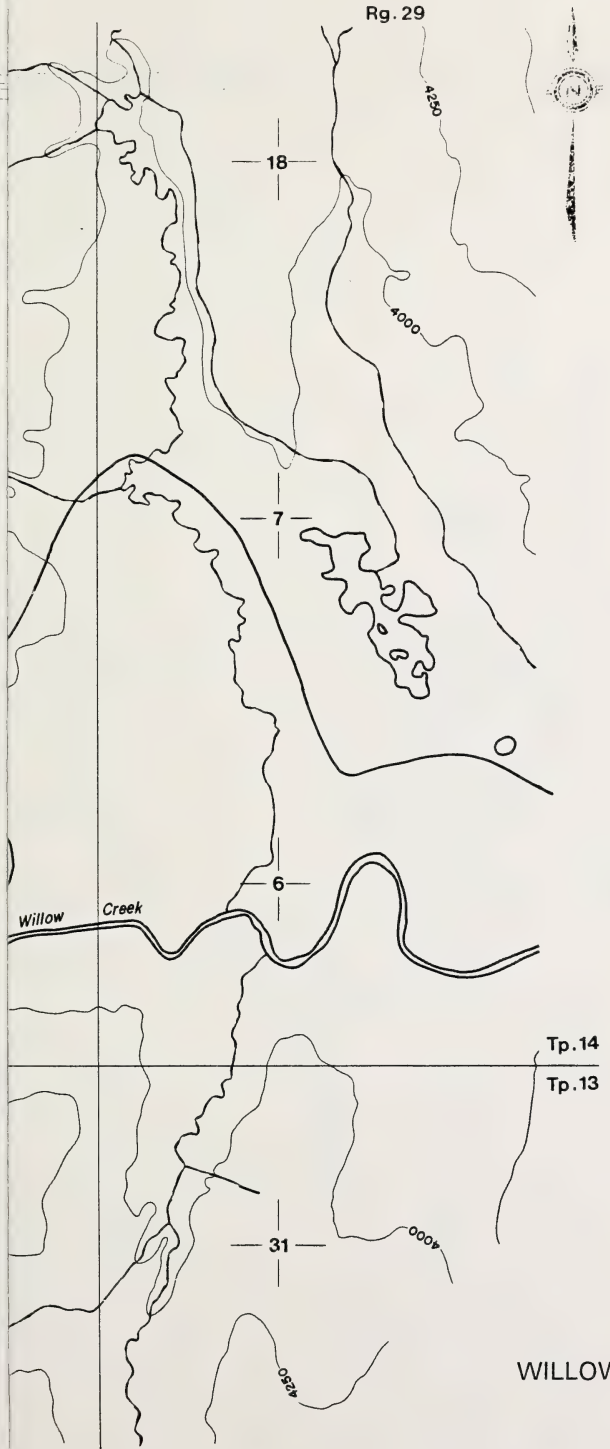
Alberta
ENVIRONMENT
Water Resources
Management Services

WILLOW CREEK STORAGE FEASIBILITY STUDY
WILLOW CREEK SITE 3

LOCATION PLAN

SCALE 1:30 000

FIGURE 5



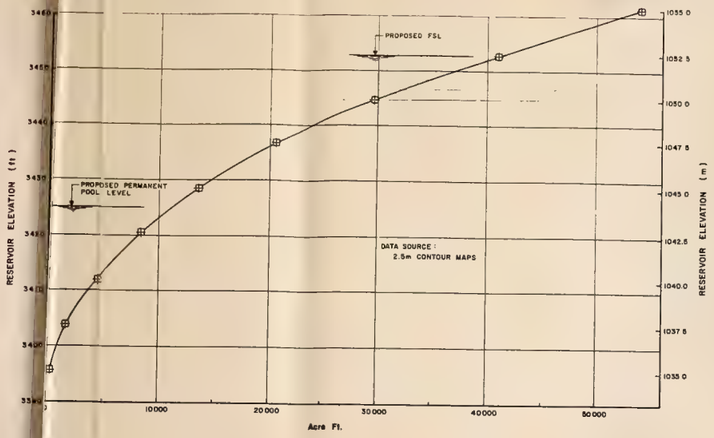
Alberta
ENVIRONMENT
Water Resources
Management Services

WILLOW CREEK STORAGE FEASIBILITY STUDY
WILLOW CREEK SITE 3

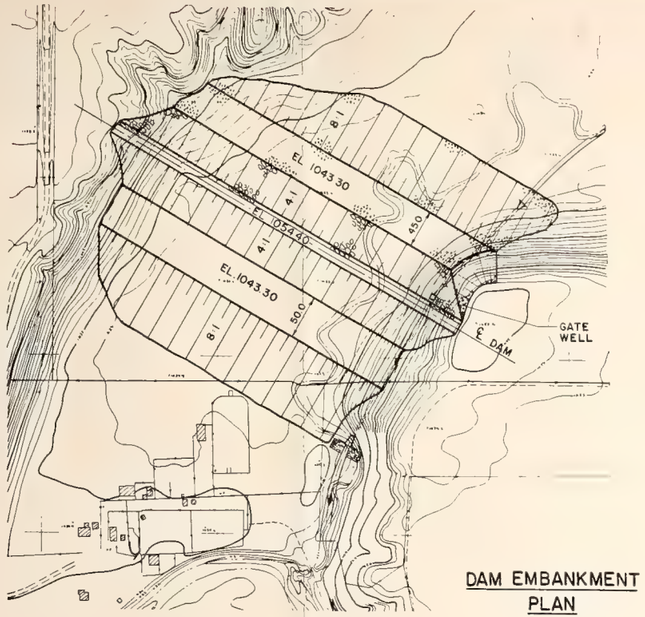
LOCATION PLAN

SCALE 1:30 000

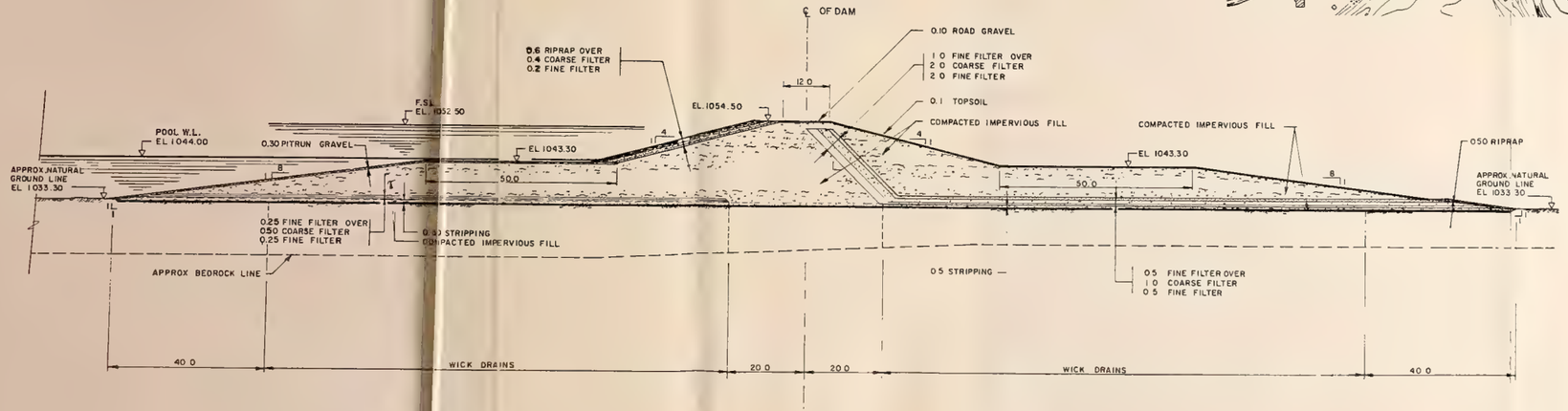
FIGURE 5



STORAGE CURVE



DAM EMBANKMENT PLAN



DAM EMBANKMENT CROSS - SECTION

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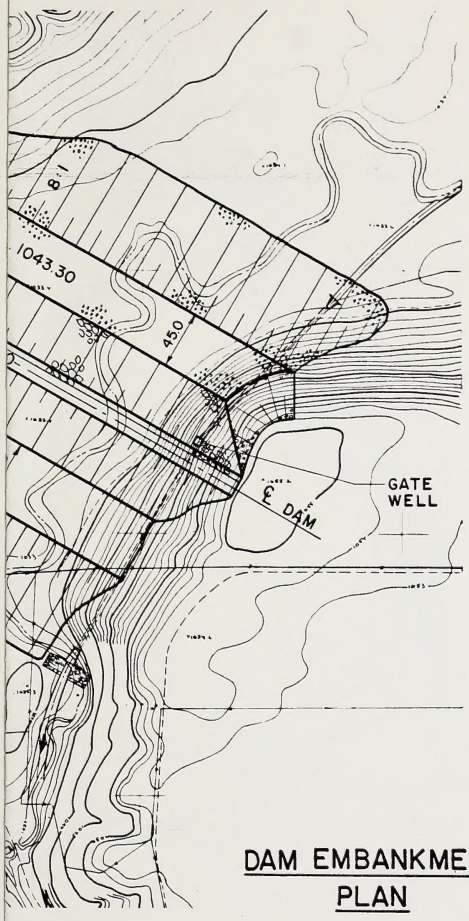
Water Resources
Management Services

WILLOW CREEK STORAGE FEASIBILITY STUDY
PINE COULEE SITE 2

GENERAL PLAN & DAM CROSS-SECTION

SCALE 1:30 000

FIGURE 6



DAM EMBANKMENT
PLAN

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NATURAL
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Alberta
ENVIRONMENT
Water Resources
Management Services

WILLOW CREEK STORAGE FEASIBILITY STUDY
PINE COULEE SITE 2

GENERAL PLAN & DAM CROSS-SECTION

SCALE 1:30 000

FIGURE 6

N.L.C. - B.N.C.
3 3286 07309536 2